Stormwater Management Appendix

A201.8 General Drainage Requirements

1. The specified design storms shall be defined as either a 24-hour storm using the rainfall distribution recommended by the U.S. Soil Conservation Service when using U.S. Soil Conservation Service methods or as the storm of critical duration that produces the greatest required storage volume at the site when using a design method such as the Modified Rational Method. Pre-development and post-development runoff rates for the 2-, 10-, and 100-year storms shall be verified by calculations that are consistent with sound engineering practices.

SCS Hydrology. SCS Hydrology consists of Technical Release Number 20 (TR-20) and Technical Release Number 55 (TR-55) including the COE HEC-1/HEC-HMS software, and other SCS applications. This hydrology is preferred and acceptable for all Stormwater Management and Floodplain analyses. All Floodplain Studies shall be prepared utilizing SCS Hydrology unless otherwise approved by the program administrator.

Other Hydrologic Methods. It is recognized that there are many hydrologic methods available, especially in the form of computer software. Other hydrologic methods may be approved by the program administrator for specific applications provided it is demonstrated that the alternatives are appropriate for the purpose intended.

2. For purposes of computing runoff, all pervious lands in the site shall be assumed prior to development to be in good condition (if the lands are pastures, lawns, or parks), with good cover (if the lands are woods), or with conservation treatment (if the lands are cultivated); regardless of conditions existing at the time of computation.

3. Impounding structures that are not covered by the Impounding Structure Regulations (4 VAC 50-20-10 et seq.) shall be engineered for structural integrity during the 100-year storm event.

4. Pre-development and post-development runoff rates shall be verified by calculations that are consistent with good engineering practices.

5. Residential lots in which lot size is less than thirty thousand (30,000) square feet shall be graded in such a manner that surface runoff does not cross more than two (2) lots before it is collected in a storm sewer system or designed stormwater conveyance channel. All surface drainage must be contained in an adequate easement once it is discharged from the third residential lot. Any concentrated stormwater must be contained in an adequate easement.

6. Hydrologic and hydraulic design calculations to demonstrate 10-year overland relief, with the storm sewer system plugged, shall be provided. Calculations for additional overlot drainage practices, shall be provided, when required by the County Engineer.

7. No stormwater conveyance pipe shall be less than 15” in diameter.

8. Storm sewer design calculations shall be performed in accordance with the practices presented in the current edition of the VDOT drainage manual.

9. All newly graded vegetated areas shall have a minimum 2% slope.

10. Erosion & Sediment Control Basins, Traps, or other constructed Improvements shall not be designed in the FEMA Regulatory Floodplain unless otherwise approved by the Program Administrator.

11. Permanent Fill Slopes exceeding a 3:1 slope ratio must be stabilized with sod or erosion control matting or other approved alternative.

A201.8 Technical Bulletins 1 and 8

Technical Bulletin No. 1

Virginia Department of Conservation and Recreation - Stream Channel Erosion Control

Virginia Department of Conservation and Recreation

Stormwater Management & Erosion and Sediment Control Program
Stream Channel Erosion Control Policy Guidance

The Virginia Department of Conservation and Recreation (Department) is responsible for the successful implementation and enforcement of Virginia's **Stormwater Management** (SWM) **Regulations** (4VAC3-20-81) and the **Erosion and Sediment Control** (ESC) **Regulations** (4VAC50-30-40.19). These regulations are consistent with one another in that they both require that: "*Properties and receiving waterways downstream of any land development project shall be protected from erosion and damage due to increases in volume, velocity, and peak flow rate of stormwater runoff . . . in accordance with . . .*" minimum design standards as defined in Minimum Standard 19 (MS-19) of the ESC Regulations, or alternate design standards as defined in the SWM Regulations. The design standards found in these regulations include a requirement for the determination of the adequacy of downstream channels, as well as design related options for when the downstream channels are inadequate for the developed condition peak flow. These design standards and options have been developed as the best available and economically achievable criteria for the protection of downstream channels and properties.
Due to the complex nature of stream channel hydraulics, however, these design options have been shown to be inconsistent in accomplishing their goal. Therefore, the Department has developed guidance for the successful implementation of the stream channel erosion control component of the SWM and ESC Regulations.

Introduction

Stream channel erosion is a natural phenomenon which, in a natural stream in an undeveloped watershed, reaches a state of equilibrium. This balance is demonstrated when the supply of sediment all along the channel reach equals the demand for (or loss of) sediment and there is no net loss of sediment from the system. As this equilibrium shifts or falls out of balance due to natural forces or events, various physical reactions help to bring it back into balance. These reactions include the development of sand bars, the growth of vegetation within the channel, and eroded stream bed and banks.

The changes to the land surface associated with development activities will bring about significant changes to a channel's natural equilibrium. As channels are consistently impacted with increased volume, velocity, and peak rates of flow, they will change by increasing their cross-sectional flow area to accommodate the higher flows. This is done either through widening of the channel banks, downcutting of the channel bed, or frequently both. Research conducted in many geographic areas has concluded that channel degradation occurs at relatively low levels of imperviousness (10-20%). (Watershed Protection Techniques,Vol 1, No.3).

This change, or degradation, is inevitable regardless of stormwater detention or other controls aimed at reducing peak rates of stormwater runoff. The well documented response characteristics of a developing watershed are increases in runoff volume, velocity, and peak rate of flow. While stormwater controls may be implemented to reduce the peak rate of runoff, the increase in runoff volume dictates that the duration of the peak rate will increase, as well as the occurrence frequency of the peak rate.

Therefore, as the level of imperviousness within a watershed increases, the question is not: "Is the channel adequate to handle the change in flow regime?", but rather: "What is the acceptable level of change or reaction within the channel to accommodate the change in flow regime?" If a natural channel is determined to be adequate, this implies that the channel has the capacity to adjust to the new flow regime without stressing the channels natural characteristics. MS-19 defines the adequacy of a natural channel by the velocity of flow associated with the two year storm being "*non-erosive*" and "*contained within the banks*". The definition of "non-erosive" is very subjective, especially when considering that the existing or pre-developed flow velocity causes erosion within the bounds of the channel equilibrium. Guidance provided in the *Virginia Erosion and Sediment Control Handbook, 1992 Edition*, Table 5-22, establishes the maximum velocities for unlined channels based on the soils which form the lining of the channel. This approach requires an analysis of the channel lining material. The potential for error is not in the accuracy of the analysis for each individual channel, but rather in the assumption that the lining material will not change as the channel reacts and reaches equilibrium under new flow conditions.

One potential solution to channel analysis related issues is to reduce the flow rate sufficiently so as to minimize the level of reaction by the channel. The amended SWM Regulations provide one such alternative design criteria: extended detention of the runoff from the 1-year frequency storm event. Extended detention decreases the flow rate and velocity from the basin sufficiently so as to offset the increases in volume, frequency, and duration of the discharge. (The extended detention of the 1-year storm event is in lieu of the detention of the 2-year frequency storm, released at the pre-developed rate.) This alternative, however, may not necessarily solve the channel erosion concern. Rather, a comprehensive analysis of the geomorphology of the channel, including the natural sediment bed load, would be needed to accurately determine the appropriate design storm and release rate for maintaining the natural level of erosion and sedimentation to support the natural channel equilibrium. Once a comprehensive geomorphological channel analysis has been completed, a design may then best reflect the need for extended detention, channel improvements, other design measures, or a combination thereof, in order to minimize or negate channel impact. This type of analysis has historically been outside the scope of the general engineering services for most development projects. Hence, a primary reason for this guidance document is to ensure that in the absence of such an analysis, the negative impacts to receiving channels is minimized.

Therefore, the effective implementation of the existing criteria in conjunction with additional design options represents the most feasible approach for protecting downstream channels and properties from damages resulting from increased rates of runoff. The following guidance provides both technical and administrative criteria which, if implemented, should help to reduce the occurrence of property damage downstream from land development projects. In addition, this guidance presents practices which promote a comprehensive look at the potential cumulative impacts to a receiving channel rather than the site by site analysis performed by individual development projects. These criteria fall within the authority of local government adopted programs to implement and enforce under the existing ESC and SWM regulations.

It is important to note that there may be situations where either existing development, new development, or a combination of the two have resulted in significant drainage and channel erosion related problems. Statewide regulations can rarely address all site specific conditions and are usually tested by development conditions and trends which were not anticipated during the drafting of local ordinances. In all cases, common sense and fairness, as well as an equal respect for the property rights of all those involved should govern in developing a strategy for solving the variety of complex design problems that may occur.

Minimum Standard 19 (4VAC50-30-40.19)

Minimum Standard 19 (MS-19) of the ESC Regulations provides criteria for the protection of properties and waterways downstream from development sites. Simply stated, "*Properties and waterways downstream from development sites shall be protected from sediment deposition, erosion, and damage due to increase in volume, velocity, and peak rate of stormwater runoff . . .* ".

This standard provides criteria for the analysis of the downstream channel, as well as the options for cases where the channel has been determined to be inadequate, or it has been determined that the increases in volume, velocity, and peak rate of runoff will result in damage.

<u>Concentrated Stormwater Runoff</u>

Section **4VAC50-30-40.19.a** of MS-19 states: ***Concentrated stormwater runoff leaving a development site shall be discharged directly into an adequate natural or man-made receiving channel, pipe or storm sewer system. For those sites where runoff is discharged into a pipe or pipe system, downstream stability analyses at the outfall of the pipe or pipe system shall be performed.***

Concentrated stormwater runoff leaving a development site, to include discharge from stormwater facilities, must be discharged directly into an adequate channel. An adequate channel can be a natural or man-made conveyance which will not erode or be overtopped by the runoff generated by the following region interpolated storm events: 2-year storm erodibility and capacity for natural channels, 2-year storm erodibility and 10-year storm capacity for man-made channels, and 10-year storm capacity for pipes. (**4VAC50-30-40.19.b** of MS-19.) Land development typically includes a site design that collects stormwater runoff from the improved surfaces of the site and conveys it in a hydraulically efficient manner to a discharge location. Where runoff was a combination of sheet flow and possibly concentrated flow in the pre-developed condition, the post-developed condition generally concentrates the runoff to either a SWM facility prior to the receiving channel, or directly to the receiving channel. In either case, there must be a receiving channel and that channel must be adequate to carry the design discharge. The discussion of options available when the channel is determined to not be adequate follows later in this section.

An important clarification must be made for "***. . . sites where runoff is discharged into a pipe or pipe system . . .***". The regulations require that a *downstream stability analysis be performed at the outfall of the pipe or pipe system*. This stability analysis includes the adequacy of the outlet protection at the end of the man-made system, as well as the adequacy of the natural receiving channel below the outlet protection. There should be no distinction between a "pipe or pipe system" and a man made conveyance channel. In other words, a stability analysis (or channel adequacy determination) should be required at the outfall of any man made conveyance system, whether it is a pipe system, or an earth, grass lined, or armored (concrete, riprap, etc) man made channel. Many examples exist where a development project proposes to discharge into a man-made channel or pipe system. The adequacy of the man-made system is easily verified. However, the adequacy of the receiving channel at the outfall of the man-made system is often ignored. This section of MS-19 requires that the downstream natural channel be evaluated for adequacy when constructing or discharging into a man-made channel or pipe system.

<u>Adequacy of Channels and Pipes</u>

4VAC50-30-40.19.b: ***Adequacy of all channels and pipes shall be verified in the following manner:***

(1) The applicant shall demonstrate that the total drainage area to the point of analysis within the channel is one hundred times greater than the contributing drainage area of the project in question; or

(2) (a) Natural channels shall be analyzed by the use of a two-year storm to verify that stormwater will not overtop channel banks nor cause erosion of channel bed or banks; and

(b) All previously constructed man-made channels shall be analyzed by the use of a ten-year storm to verify that stormwater will not overtop its banks and by the use of a two-year storm to demonstrate that stormwater will not cause erosion of channel bed or banks; and

(c) Pipes and storm sewer systems shall be analyzed by the use of a ten-year storm to verify that stormwater will be contained within the pipe or system.

(1) One-percent rule

Item (1), commonly referred to as the one-percent rule, provides for a receiving channel to be considered adequate if the contributing drainage area to the discharge point is 100 times greater than the contributing drainage area of the project in question. The theory is that the increase in runoff associated with the development project will be insignificant when compared to the peak discharge associated with a watershed of such magnitude. For example, the increase in peak discharge from a ten acre development project which discharges directly into a stream channel with a contributing drainage area of 1,000 acres or more will have very little impact on that channel. The channel is automatically assumed to be adequate to handle the increase in runoff. Adequate conveyance to the stream channel, however, is required.

The exception to this may be in cases where the stream channel is experiencing significant erosion due to existing levels of development. While it should not be the sole responsibility of any one development or current project to remedy the eroding channel, new development should not add to or exacerbate a deteriorating condition. Rather, the local plan approving authority should identify solutions based on a comprehensive analysis of the contributing drainage area or watershed. Simply requiring all new development to implement on site detention structures may not provide adequate controls at the appropriate locations in the watershed in order to provide an overall benefit to the stream system.

(2) Channel Analysis

Item (2) provides the criteria for determining if a natural or man-made channel is adequate. An accurate determination of the channel geometry, lining, and slope, as well as an accurate hydrologic analysis of the contributing drainage area are critical to meeting this criteria.

- **Channel geometry** - A minimum of three surveyed cross-sections should be taken at a minimum spacing of 50' along the channel length downstream of the discharge point. The channel top of bank should be well defined and identifiable by field parameters such as a flattening or change in bank slope, flattened vegetation in the direction of the flow, soil types, or other obvious indicators of frequent flow levels. When the top of bank does not appear to be obvious, a hydrologic analysis of the contributory drainage area and the corresponding 2-year undeveloped peak discharge may be used to define the cross-sectional flow area using Manning’s equation.

- **Channel lining** - A sample of the channel lining material should be collected and analyzed to determine the composition relative to the permissible velocities found in Table 5-22 of the *Virginia Erosion and Sediment Control Handbook, 1992 Edition*.

- **Channel slope -** Relative elevations should be taken along the channel length (at the surveyed cross-sections at a minimum) in order to determine the average longitudinal slope of the channel.

- **Energy slope -** A hydraulic grade line calculation should accompany any analysis of an existing or proposed pipe system to verify that the flow is contained within the system during the 10-year frequency storm.

The submission of this data, along with the hydrologic analysis of the contributing drainage area, should be accompanied by a written certification that the collected data represents the channel's typical geometry, lining, and slope. In order to support the accuracy of this certification, the designer should physically inspect the channel by walking its length to determine that there are no significant changes or obstructions which may restrict the flow and cause it to jump the banks or increase in velocity to an erosive level. The designer should ensure that there are no undersized culverts or other "improved" restrictions downstream of the development. Any such restrictions should be identified and investigated to determine the party responsible for upgrade or repair. The length of channel covered by such an inspection is dependent on the channel size and contributing drainage area. Common sense and sound engineering judgement should govern. A general guideline, however, is to proceed downstream to a point at which the one-percent rule applies: the contributing drainage area is one hundred times the project size.

In cases where a channel analysis determines that the velocity of the developed condition runoff is less than the critical threshold as provided in the Erosion and Sediment Control Handbook, it may be optimistic to assume that no channel degradation will occur. The velocity of the developed condition runoff is only one parameter in the analysis of the impacts of development on a natural channel. The volume, duration, and frequency of peak flows can also play a critical role in channel erosion.

<u>Inadequate Channels</u>

4VAC50-30-40.19.c. ***If existing natural receiving channels or previously constructed man-made channels or pipes are not adequate, the applicant shall:***

(1) ***Improve the channel to a condition where a ten-year storm will not overtop the banks and a two-year storm will not cause erosion to the channel bed or banks; or***

(2) ***Improve the pipe or pipe system to a condition where the ten-year storm is contained within the appurtenances; or***

(3) ***Develop a site design that will not cause the pre-development peak runoff rate from a two-year storm to increase when runoff out falls into a natural channel or will not cause the pre-development peak runoff***

> ***rate from a ten-year storm to increase when runoff out falls into a man-made channel; or***
>
> ***(4) Provide a combination of channel improvement, stormwater detention or other measures which is satisfactory to the plan-approving authority to prevent downstream erosion.***

The inadequacy of a channel is based on the erosiveness of the channel bed or banks or the capacity of the bank full channel geometry. The alternatives listed above provide generic solutions for most situations.
However, the practical implementation of these alternatives may, in some cases, be cost prohibitive, or restricted by access and environmental issues.

In some cases there may be **no** receiving channel. This is a common occurrence in areas underlain by karst topography. Development in regions underlain by karst topography present a unique set of challenges with regard to drainage. Most natural drainage ways gradually become more defined (channel bed and banks) as you move down in the watershed. Channels in areas underlain by karst topography, however, may gradually become less defined or even disappear altogether as you move down slope. Not only does this present a problem in discharging to an adequate channel or determining channel adequacy, but more importantly, the increased runoff associated with development may cause solution channels to develop and ultimately lead to karst collapse. Guidance on the implementation of stormwater management strategies in regions underlain by karst topography is provided in **Chapter 4-5**.

A natural channel is defined as a conveyance with a defined cross sectional flow area. In cases where no channel exists, a channel (man-made channel) to convey the flow to an adequate outfall must be provided. Converting the developed condition runoff to sheet flow rather than providing a channel is a very difficult option to successfully implement. The increased volume and frequency of runoff associated with impervious cover will act to reconcentrate the flow resulting in potential downstream impacts. This option should be accompanied by a drainage easement from the downstream property owner in order to facilitate the monitoring of the flow conditions and possibly providing an adequate channel if necessary.

(1) Improving the Channel

Channel improvements, in cases where an existing natural channel is determined to be inadequate, are not limited to rip-rap and concrete. Significant advances in bioengineering materials and methods have proven very effective in protecting and restoring natural channels. The Erosion and Sediment Control Regulations require that ***"all measures used to protect properties and waterways shall be employed in a manner which minimizes impacts on the physical, chemical and biological integrity of rivers, streams and other waters of the state."*** (4VAC50-30-40.19.k). Likewise, the Stormwater Management Regulations require that ***"Natural channel characteristics shall be preserved to the maximum extent practicable."*** (4VAC3-20-60.K). Improvements to existing manmade channels, however, may certainly consist of armoring with an erosion resistant material such as rip rap, gabion baskets, or concrete. The regulations require that ***"the applicant shall provide evidence of permission to make the improvements."***(4VAC50-30-40.19.d) This includes any necessary permits as well as permission to access private property.

(2) Improving Pipes or Pipe Systems

Under ideal conditions, pipe systems would have been built to accommodate ultimate development conditions and, therefore, limit the need for the reconstruction of a pipe system. The establishment of drainage easements for storm sewer systems which convey off site water through private development will allow for improvements or upgrades as needed. Reconstruction of a pipe system will often cause significant disruption of the existing use of a property. For this reason permission to access private property may be denied without the presence of easements to ensure that needed improvements can be made. In addition, the potential expense of avoiding existing utilities and other obstacles when replacing an existing storm sewer system may make this a very costly option. Possible alternatives include a separate pipe system or otherwise diverting flows around the undersized system.

(3) Alternative Site Designs

This provision has, in the past, been interpreted to require the detention of the post-developed runoff from the 2- and 10-year frequency storm, released at the respective pre-developed rates. Detention, however, is only mentioned in conjunction with *". . . channel improvements or other measures satisfactory to the plan-approving authority to prevent downstream erosion"* (item 4 below). Further, the concept of a site design which *". . .will not cause the pre-development peak runoff rate to increase . . ."* implies much more than stormwater detention as a solution. Recently, significant attention has been focused on Low-Impact Development (LID) and other site design techniques aimed at reducing the developed condition volume and frequency of runoff. Support for these techniques is found in the knowledge that stormwater detention structures do not mitigate all of the impacts of development on the hydrologic cycle. The emphasis within this provision should be on low impact development practices which are focused on hydrologic principals: site design as the mechanism for maintaining the pre-developed rate and volume of runoff.

Site design practices which encourage groundwater recharge, minimization and disconnection of impervious surfaces, preservation of open space and stream corridors, tree preservation, etc. have been proven to reduce the developed condition stormwater runoff and nonpoint source pollutant load. These practices used in conjunction with a water quality BMP which targets the first flush can significantly alter the developed condition hydrograph to more closely replicate that of the pre-developed condition. While this may not be viable in all development situations, there is a great deal of evidence to support it as integral component of any proposed solution to controlling the increased volume and rate of peak discharges.

Significant work in this area has been accomplished and is ongoing. Rather than duplicate the volumes of information available, the reader is referred to the following references for information on low impact development practices and site design techniques.

Center for Watershed Protection. 1998. Better Site Design: A Handbook for Changing Development Rules in Your Community.

Delaware Department of Natural Resources and Environmental Control (DE DNREC). 1997. Conservation Design for Stormwater Management.

Prince George County Department of Environmental Resources (PGDER). 1997. Low-Impact Development Design Manual.

Schueler, T. Center for Watershed Protection 1995. Site Planning for Urban Stream Protection. Prepared for: Metropolitan Washington Council of Governments, Washington D.C.

Center for Watershed Protection. 1998. Nutrient Loading from Conventional and Innovative Site Development. Prepared for: Chesapeake Research consortium.

Center for Watershed Protection. 2000. Better Site Design - A Guidebook for Communities implementing the Chesapeake Bay Preservation Act. Prepared for Virginia Chesapeake Bay Local Assistance Department.

Virginia Chesapeake Bay Local Assistance Department, 1989. Local Assistance Manual.

(4) Combination of Channel Improvements, Detention, and Other Measures

This alternative is very broad in that a combination of methods may be implemented to address channel stability and downstream erosion, water quality, and peak rates of runoff. The designer is required to identify a solution which is satisfactory to the plan approving authority to protect the downstream channel and/or properties. In some cases the solution may be innovative with no real guarantee or proven track record of success. Many plan-approving authorities may be reluctant to allow their locality to be the test market for new or unproven ideas. At some point however, these innovative ideas must be tested. Therefore, an applicant may choose to bond such improvements for a reasonable period of time in order to document the success of the efforts. This is an approach similar to that used in wetland mitigation, as well as other resource protection permits, where the impacts to the environmental systems are uncertain.

Nowhere in the ESC or SWM regulations is it provided that the detention of the two- and ten-year frequency storms reduced to pre-developed levels is an automatic solution to the lack of an adequate channel. Further, there is sufficient evidence that in many cases this may not be an adequate solution due to the increase in frequency and duration of peak flows. A comprehensive solution, as suggested in this alternative, may include low impact development practices, bioengineering of the receiving channel to ensure stability, and detention of peak flows. Alternative detention criteria for sensitive stream channels, or channels experiencing erosion under existing conditions should consider 24 hour extended detention of the runoff from the 1-year frequency storm, as this is recognized as being a significantly more effective criteria for protecting natural channels. In addition, the consultant may propose a detention solution based on the conditions of the downstream channel geomorphology.

Ultimate Development Conditions

4VAC50-30-40.19.j (E&S) and 4VAC3-20-60.H (SWM) require that *" . . . individual lots or parcels in a residential, commercial or industrial development shall not be considered to be separate development projects. Instead, the development, as a whole, shall be considered to be a single development project. Hydrologic parameters that reflect the ultimate development condition shall be used in all engineering calculations."*

This requirement benefits the overall development strategy in that adequate drainage infrastructure is required so as to allow the individual development of parcels or lots within the overall project without disruption for reconstruction of undersized components. This is a sound environmental, as well as economic, strategy for development. This strategy should also be applied to developing watersheds. As individual parcels develop within a watershed, an overall drainage/watershed management strategy should identify the natural drainage ways and the properties through which they drain. As these properties develop, the ultimate development conditions should be considered for the design of the drainage conveyance through the individual projects. This should include drainage easements in order to facilitate future access and maintenance.

The timing of development within a drainage area should not unfairly place the burden of conveyance and outfall stream channel protection on one contributor of runoff, nor should it dictate the stormwater management requirements within the developing watershed. The drainage system carrying off-site water through a site should be placed within a drainage easement and the design of that system based on the ultimate development conditions of the drainage area above the site. Additional costs associated with the construction of the ultimate development condition drainage system should be shared through a program where the contributing properties pay based on their contribution of runoff or peak flow rate (pro-rata share contribution). If the development of the upstream drainage area is in doubt, then the presence of an easement will at least facilitate the upgrade of the existing system if or when the future development occurs.

If the ultimate development condition upstream is ignored and the system is sized for existing conditions with no easements, then the SWM policies for the upstream watershed are dictated by the undersized system. Consider if the timing were reversed and the upper portions of the watershed were developed first, surely the lower properties would then be forced to construct a system to convey the developed condition flows through the site.

4VAC50-30-40.19.e states that *"All hydrologic analyses shall be based on the existing watershed characteristics and the ultimate development of the subject project."* This should be applied when determining the impact of the project in question. However, once the determination is made to access the stream channel and make improvements, those improvements should be based on ultimate development condition flows. The stability of the outfall and receiving channel for any improved conveyance system should also be analyzed based on the ultimate development conditions. This will minimize the impact to the receiving channel by limiting the number of times the channel is accessed by construction equipment. In addition, this will allow stabilization of any bioengineering improvements prior to full build out and ultimate development peak flows. Again, a pro-rata share funding strategy should be implemented to equitably assess the properties which contribute runoff.

In all cases, the design of drainage infrastructure for future development should be based on zoning and the associated anticipated densities of imperviousness. If the zoning changes due to a rezoning request, changes to the comprehensive development plan, or some other mechanism, than conditions of that change should include an update of the drainage plan and pro-rata share contribution program. For this reason, drainage easements should be required for all drainage ways which carry public or off-site runoff through private property. This will ensure the ability to maintain or upgrade the drainage system if conditions dictate.

As discussed previously, the ability to predict the response of a natural channel to changes in the upstream hydrology or flow regime is a very subjective analysis. Further, the level of "damage" can also be subjective. A large volume of sediment deposited within a channel during a storm event is certainly an obvious sign of a channel becoming out of balance or attempting to find a new equilibrium. The sediment may be from a construction site or other external source, or it may be the result of the reaction or change within the channel due to increased flows. Regardless, the erosion process begins slowly and quickly accelerates. The ideal solution is a preventive solution which focuses on decreasing the impact of development on the hydrologic cycle.

4VAC3-20 Virginia Stormwater Management Regulations

4 VAC 3-20-81. Stream channel erosion.

A. Properties and receiving waterways downstream of any land development project shall be protected from erosion and damage due to increases in volume, velocity and peak flow rate of stormwater runoff in accordance with the minimum design standards set out in this section.

B. The plan approving authority shall require compliance with subdivision 19 of 4 VAC 50-30-40 of the Erosion and Sediment Control Regulations, promulgated pursuant to Article 4 (§ 10.1-560 et seq.) of Chapter 5 of Title 10.1 of the *Code of Virginia*.

C. The plan approving authority may determine that some watersheds or receiving stream systems require enhanced criteria in order to address the increased frequency of bankfull flow conditions brought on by land development projects. Therefore, in lieu of the reduction of the 2-year post-developed peak rate of runoff as required in subsection B of this section, the land development project being considered shall provide 24-hour extended detention of the runoff generated by the 1-year, 24-hour duration storm.

D. In addition to subsections B and C of this section, localities may, by ordinance, adopt more stringent channel analysis criteria or design standards to ensure that the natural level of channel erosion, to the maximum extent practicable, will not increase due to the land development projects. These criteria may include, but are not limited to, the following:

1. Criteria and procedures for channel analysis and classification.
2. Procedures for channel data collection.
3. Criteria and procedures for the determination of the magnitude and frequency of natural sediment transport loads.
4. Criteria for the selection of proposed natural or man-made channel linings.

4VAC50-30 Virginia Erosion and Sediment Control Regulations

4VAC50-30-40. Minimum Standards

19. Properties and waterways downstream from development sites shall be protected from sediment deposition, erosion and damage due to increases in volume, velocity and peak flow rate of stormwater runoff for the stated frequency storm of 24-hour duration in accordance with the following standards and criteria:

a. Concentrated stormwater runoff leaving a development site shall be discharged directly into an adequate natural or man-made receiving channel, pipe or storm sewer system. For those sites where runoff is discharged into a pipe or pipe system, downstream stability analyses at the outfall of the pipe or pipe system shall be performed.

b. Adequacy of all channels and pipes shall be verified in the following manner:

(1) The applicant shall demonstrate that the total drainage area to the point of analysis within the channel is one hundred times greater than the contributing drainage area of the project in question; or

(2) (a) Natural channels shall be analyzed by the use of a two-year storm to verify that stormwater will not overtop channel banks nor cause erosion of channel bed or banks; and

(b) All previously constructed man-made channels shall be analyzed by the use of a ten-year storm to verify that stormwater will not overtop its banks and by the use of a two-year storm to demonstrate that stormwater will not cause erosion of channel bed or banks; and

(c) Pipes and storm sewer systems shall be analyzed by the use of a ten-year storm to verify that stormwater will be contained within the pipe or system.

c. If existing natural receiving channels or previously constructed man-made channels or pipes are not adequate, the applicant shall:

(1) Improve the channel to a condition where a ten-year storm will not overtop the banks and a two-year storm will not cause erosion to the channel bed or banks; or

(2) Improve the pipe or pipe system to a condition where the ten-year storm is contained within the appurtenances; or

(3) Develop a site design that will not cause the pre-development peak runoff rate from a two-year storm to increase when runoff out falls into a natural channel or will not cause the pre-development peak runoff rate from a tenyear storm to increase when runoff out falls into a man-made channel; or

(4) Provide a combination of channel improvement, stormwater detention or other measures which is satisfactory to the plan-approving authority to prevent downstream erosion.

d. The applicant shall provide evidence of permission to make the improvements.

e. All hydrologic analyses shall be based on the existing watershed characteristics and the ultimate development of the subject project.

f. If the applicant chooses an option that includes stormwater detention he shall obtain approval from the locality of a plan for maintenance of the detention facilities. The plan shall set forth the maintenance requirements of the facility and the person responsible for performing the maintenance.

g. Outfall from a detention facility shall be discharged to a receiving channel, and energy dissipaters shall be placed at the outfall of all detention facilities as necessary to provide a stabilized transition from the facility to the receiving channel.

h. All on-site channels must be verified to be adequate.

i. Increased volumes of sheet flows that may cause erosion or sedimentation on adjacent property shall be diverted to a stable outlet, adequate channel, pipe or pipe system, or to a detention facility.

j. In applying these stormwater runoff criteria, individual lots or parcels in a residential, commercial or industrial development shall not be considered to be separate development projects. Instead, the development, as a whole, shall be considered to be a single development project. Hydrologic parameters that reflect the ultimate development condition shall be used in all engineering calculations.

k. All measures used to protect properties and waterways shall be employed in a manner which minimizes impacts on the physical, chemical and biological integrity of rivers, streams and other waters of the state.

Stormwater Management Technical Bulletin No. 8

VECTOR CONTROL
Mosquitoes & Stormwater Management

Introduction

Recently in Virginia, an increasing number of animals and humans have tested positive for the mosquito-borne West Nile virus. Mosquitoes are the world's most significant vectors (a "vector" refers to any organism that can transmit an infectious disease pathogen to another organism). Diseases transmitted by mosquitoes are responsible for the deaths of millions of people worldwide every year. Infections transferred by vectors are referred to as vector borne diseases, and include Eastern Equine Encephalitis, dog heartworm, and West Nile virus found in Virginia.

Statewide, questions have arisen on vector control ("vector control" refers to the process of eradicating or controlling the disease-carrying insects), especially in standing waters in ponds and stormwater ditches. Ponded waters, such as constructed stormwater management facilities (detention areas, storm sewers, and stormwater ditches), have the potential to foster mosquito reproduction. However, stormwater management is crucial to protect our environment and downstream properties and communities. Stormwater management practices are essential to protect stream banks from eroding, to remove pollutants from the waterways, to recharge groundwater, and to control flooding to protect downstream properties and people. Careful planning, design and maintenance of stormwater management practices are necessary to eliminate or to minimize the proliferation of disease-carrying mosquitoes.

This technical bulletin discusses stormwater management measures designed and maintained to eradicate or control mosquito habitat to prevent the spread of diseases carried by mosquitoes.

Background

There are approximately 55 species of mosquitoes present in Virginia. Currently, a survey of mosquito populations associated with stormwater management facilities has not been conducted. However, it is estimated that 6 mosquito species breed in temporary bodies of water, of which a majority are potential vectors of the West Nile virus. Also, it is estimated that 4 mosquito species breed in permanent bodies of water, of which none are known to carry the West Nile virus. Finally, there are 2 mosquito species that breed in both permanent and temporary bodies of water that may be vectors of the West Nile virus.

A mosquito's lifecycle has four stages – egg, larva, pupa, and adult. Mosquitoes need water to breed since all mosquitoes spend their larval and pupal states in water. Most mosquitoes breed in temporary standing waters that are less than one foot deep, when nutrients are available for feeding and the water temperature is acceptable. The lifecycle between egg and adult varies from 8 days to 2 weeks. Natural predators of mosquitoes include birds, dragonflies, many other aquatic insect species, fish and spiders.

Urban environments provide numerous mosquito breeding grounds: around homes (birdbaths, jars, flower pots, clogged rain gutters, neglected pools), in unregulated waste dumps (tires, barrels, bottles, cans), in shallow natural aquatic areas, and in improperly maintained or constructed stormwater management and flood control structures (storm drains, sewer systems, catch basins, settling ponds). The pervasiveness of these habitats allows many species of mosquitoes to extend in reach and numbers, thereby increasing the threat of mosquitoes as vectors of numerous diseases.

Stormwater management facilities (such as temporary erosion and sediment control basins and traps, permanent retention ponds, storm sewers and stormwater ditches to a lesser degree) may increase mosquito-breeding habitats. Improperly locating and designing new stormwater management facilities may increase the mosquito population. Also, poor maintenance or improperly constructed stormwater management facilities (for both temporary erosion and sediment control and permanent stormwater management) may result in mosquito propagation. Since stormwater management practices are essential to protect our environment and properties, the method of designing, locating, and maintaining stormwater management structures is a vital step to minimize or eliminate mosquitoes.

Maintenance of Existing Stormwater Management Facilities for Mosquito Control

Some mosquito habitats may be fostered by the lack of maintenance and improper construction of stormwater management facilities (for both temporary erosion and sediment control structures and permanent stormwater management ponds and storm sewers and stormwater ditches). Vegetative overgrowth including floating algae, sediment, trash, dead grass, emergent aquatic grasses and weeds, and cattails, provides hiding places and a nutrient rich environment for mosquitoes. Clogged outlets that temporarily pond water will provide good mosquito breeding habitats. Small temporary bodies of water do not support the predator populations that keep mosquito populations in check. Inadequate drainage in constructed wetlands and dry ponds causes small puddles to remain at the base, especially adjacent to the outflow pipe. Corrugations in storm sewers may cause standing water. The following list itemizes some maintenance principles that may reduce the mosquito population.

1. Maintain and clean-out temporary erosion and sediment control traps and basins.
2. Maintain stormwater ditches (such as road side ditches) to ensure positive drainage.
3. Conduct annual vegetative management, such as removing weeds and restricting growth of aquatic vegetation to the periphery of wet ponds.
4. Remove grass cuttings, trash and other debris, especially at outlet structures.
5. Avoid producing ruts when mowing (water may pool in ruts).
6. CAUTION: Dry ponds and underground structures usually detain water for periods less than 30 hours. If they retain water for longer than five days, they are poorly maintained.
7. CAUTION: Infiltration trenches and sand filters structures should not hold water for longer than 24 hours. If they retain water for longer than 48 hours, they are poorly maintained.
8. Contact the Virginia Department of Transportation (Tel. 800-367-7623) to report standing water in ditches along state roads or suspected standing water in storm sewer systems along state roads.

Site Design for Mosquito Control

New stormwater management structures that may foster mosquito propagation include: the vegetative fringe encircling ponds where mosquitoes breed and avoid predators; shallow or semi-permanent ponds such as catch basins and riprap settling basins; structures that drain longer than designed, these areas can create stagnant pools without a resident predator population to keep mosquitoes under control naturally; and pools of water in storm drains.

The following stormwater management design tips may limit mosquito-breeding potential.

1. Reduce the need for stormwater management facilities. Design sites to preserve natural drainage and natural treatment systems to reduce the need for additional structural stormwater management facilities. Urban development impacts on natural hydrology and water quality can be reduced significantly when better site design (such as Low Impact Development) is utilized. Better site design reduces the amount of stormwater runoff, provides for natural on-site control of runoff, and thereby reduces the number of structural measures needed. Examples and design procedures may be found in the Virginia Stormwater Management Handbook, Northern Virginia's Regional Commission's Nonstructural Urban BMP Handbook, and the Center for Watershed Protection Better Site Design Manual (see website links below).

2. Improve designs of permanent pools. There are two methods for designing a permanent pool pond to reduce mosquito propagation: minimizing shallow depths (1.0 foot or less) and increasing circulation in ponds. Deep pools of water are preferable to shallow ones for mosquito control. Wet ponds and man-made wetlands should be designed to support continuous water flow to prevent stagnation and vegetative growth. Prevent shallow water by steeply grading both the banks of the pond and the impoundment. Include mechanical aerators in wet ponds, such as a fountain in the middle of the ponds, which make the site more attractive, deter the growth of unwanted vegetations, and improve the habitat for predators of mosquitoes. The principal outlet, such as a weir or riser, should have positive drainage, such as a 0.1 foot vertical drop from the low flow inlet to the outlet barrel. Also, 'inlet shaping' should be utilized in risers and junctions. Inlet shaping (or a sweep) is a construction method that installs concrete at a curve at the junctions of drop inlets or risers and storm sewer pipe and helps maintain hydraulic efficiency of risers and pipes while preventing stagnant pools of water. Please note: narrow vegetative fringes around permanent ponds will not produce significant numbers of mosquitoes, and most of the mosquito species that utilize these fringe habitats are not recognized as important West Nile virus vectors.

3. Select stormwater management measures based on site -specific conditions. Site conditions, such as soils, topography, depth to rock, depth of seasonal high groundwater table, and Karst, significantly affect the performance of stormwater management facilities. Designs that take into account the site conditions will improve drainage and limit the occurrence of stagnant water. Chapter 3 of the Virginia Stormwater Management Handbook details the site requirements for various stormwater management structures. This document can be obtained on DCR's website, provided below.

4. Take special care for ponds that temporarily impound water. Some stormwater management measures, such as dry ponds and man-made wetlands, pond water for an extended period. These facilities must drain the water completely within 30 hours of the storm event. The bottoms of the ponds must have positive drainage and be free of depressions. Avoid the placement of dry ponds and underground structures in areas where they are likely to remain wet (i.e., high water tables). Ensure that pond bottoms have a low-flow channel and a minimum of 1 to 2% bottom slope to prevent scour and stagnation. The principal outlet, such as a weir or riser, should have positive drainage, such as a 0.1 foot vertical drop from the low flow inlet to the outlet barrel. Also, if water quality orifices are required in the principal outlet structure, ensure that the minimum size is greater than 2"-3", to prevent clogging and stagnant pools of water ponding at the outlet structure. If the orifice required is less than 2" to meet water quality requirements, then another type of stormwater management facility should be considered. Also, there are manufactured methods to prevent clogging of the primary water quality outlet without restricting the hydraulic capacity of the outlet control orifices, including the installation of a trash racks.

5. Take care in the design of storm sewer systems. The sheltered environment inside storm drains can be ideal for mosquito breeding. Design and construct pipes at a rate of flow that flushes the system of sediment and prevents water backing up in the pipe (an acceptable minimum slope is 2%, as site conditions allows). Construct storm drains (such as manholes, inlets and boxes) so that the invert out is at the same elevation as interior bottom to prevent standing water. Also, 'inlet shaping' should be utilized in risers and junctions. Inlet shaping (or a sweep) is a construction method that installs concrete at a curve at the junctions of drop inlets or risers and storm sewer pipe and helps maintain hydraulic efficiency of risers and pipes while preventing stagnant pools of water. Verify that newly constructed storm sewer systems have positive drainage (see section below) and that standing water does not exist inside the system. Corrugations in storm sewers may cause standing water Contact the Virginia Department of Transportation or the local government regarding specific locality requirements for designing and maintaining storm sewer systems.

6. Require "as -builts". As-builts are survey drawings of stormwater management facilities after construction and provide sufficient information to demonstrate that the facility as constructed conforms to all specifications and requirements of the approved design plan. As-builts provide assurance that stormwater management facilities are effectively minimizing mosquito propagation. At a minimum, as-builts should include spot elevations (high and low points), contour lines, and indicate the slope of the ground. For example, the as-built confirms that dry ponds are draining and permanent pools have the necessary depth. The appendix of Chapter 3 of the Virginia Stormwater Management Handbook outlines the minimum requirements for completing an as-built. This document can be obtained on DCR's website, provided below.

7. Require and comply with a written maintenance agreement. City, County and State governments require owners to develop a written maintenance agreement for all stormwater management facilities. The maintenance agreement should require weed control and the removal of grass cuttings and other debris from the outlet structures. Also, the agreement should identify landowners and successors to maintenance requirements and obligations. The appendix of Chapter 3 of the Virginia Stormwater Management Handbook outlines the minimum requirements for a complete plan. This document can be obtained on DCR's website, provided below.

Mosquito Control Using Pesticides

When source reduction and water management are not feasible or have failed, the judicious application of insecticides, including larvicides and adulticides, may be used to control both immature and adult mosquito populations. "Larvicides" are used to kill immature mosquitoes (larvae) when applied to standing water where larvae are present. "Adulticides" are used to kill adult mosquito populations in an area where a vector population has escaped larval control. **Pesticides generally do not provide long -term solutions to controlling mosquitoes, but may be the only choice available to control mosquitoes from some habitats** . Contact your local government for more information about programs to control disease-carrying mosquitoes in your area. Contact the Virginia Department of Agricultural & Consumer Services (VDACS) for any other pesticide application questions. Also, the Virginia Department of Health has developed a West Nile Virus Surveillance and Response Plan, now on their website, that provides mosquito control guidelines for the reduction or prevention of disease transmission to humans and their domestic animals by mosquito vectors.

Further Information

For further information, please contact the following agencies:

- Virginia Department of Conservation and Recreation (www.dcr.state.va.us) 1-877-42WATER
- Virginia Department of Health (www.vdh.state.va.us) 804-786-6261
- Virginia's West Nile Virus Surveillance and Response Plan (http://www.vdh.state.va.us/epi/wnvsrplan/AvianPlan.asp)
- Your local health department
- The Virginia Department of Agricultural & Consumer Services (http://www.vdacs.state.va.us/) 804-371-6560
- Virginia Mosquito Control Association (VMCA) (http://www.mosquito-va.org/)
- U. S. Centers for Disease Control and Prevention www.cdc.gov/ncidod/dvbid/westnile/index.htm
- American Mosquito Prevention and Control Association http://www.mosquito.org/
- EPA Pestic ides & Mosquito Control www.epa.gov/pesticides
- Chesapeake Bay Local Assistance Department – Better Site Design Manual http://www.cblad.state.va.us/public a.cfm
- Low Impact Development (LID) Center - http://www.lowimpactdevelopment.org/ (301-982-5559)
- Hampton Road Planning District Commission - http://www.hrpdc.org/publications/techreports/pep.shtml
- Northern Virginia Regional Commission - http://www.novaregion.org/bmp.htm

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- "Disease Vectors Associated with Structural BMPs", Dean F. Messer, et al [Stormwater, The Journal for Surface Water Quality Professionals, March/April 2002]
- "More Than One Risk From Mosquitoes", Janice Kaspersen [Stormwater, The Journal for Surface Water Quality Professionals, March/April 2002]
- University of Florida Extension, http://disaster.ifas.ufl.edu/PDFS/CHAP04/D04-21.PDF
- Maryland Department of the Environment, http://www.mde.state.md.us/assets/document/sedimentStormwater/BMP_westnile.pdf
- Montgomery County, Maryland – Department of Environmental Protection, http://www.montgomerycountymd.gov/mc/services/dep/Mosquito/facts.pdf
- Rhode Island Office of Mosquito Abatement Coordination, http://www.uri.edu/research/eee/mosquito.html
- California Department of Health Services, Vector-Borne Disease Section, http://www.caltrans.ca.gov/hq/env/stormwater/workshop/12_01/description/metzger.htm

A201.8.1.B Stream Channel Erosion

1. The plan approving authority may determine that some watersheds or receiving stream systems require enhanced criteria in order to address the increased frequency of bankfull flow conditions brought on by land development projects. Therefore, in lieu of the reduction of the 2- and 10-year post-developed peak rate of runoff as required in subsection 201.8.1.A.2 of this Manual, the land development project being considered shall provide 24-hour extended detention of the runoff generated by the 1-year, 24-hour duration storm at the discretion of the plan approving authority.

A201.8.10 Maintenance and Access Easements

SWM/BMP and Drainage Easement Widths

Pipe Diameter	Minimum Easement Width
15” – 23”	10’
24” – 32”	20’
33” – 48”	25’

Pipe Depth	Minimum Easement Width
0’ – 9.9’	10’
10’-19.9’	20’
20’+	30’

Minimum Access Road Width = 8’
Minimum Access Road Easement = 10’

Access Roads

% of Grade	Road Treatment
0% - 3.49%	grass
3.5 % - 6.99%	compacted gravel mix (21-A)
7.0% - 12.0%	pavement